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Creating resilient habitat for the future: Building Climate Future Plots

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EXECUTIVE SUMMARY

This report outlines a vision stemming from the "Building Climate Future Plots" workshop run at the Arthur Rylah Institute, facilitated by VicNature2050. This workshop brought together scientists, managers and practitioners to develop a framework for Climate Future (CF) Plots – plots aimed at enhancing climate resilience of our natural landscapes and acting as a dynamic resource for informing future land management actions.

Climate and environmental change are having an enormous impact on our natural systems. These impacts include both direct effects on organisms by altering physical habitat conditions, as well as indirect effects through changes in biotic interactions. Whilst changes in average conditions are altering many ecological processes, changes in the incidence of extreme events are having equivalent or even larger effects.

Despite this, there is evidence that some systems can adapt at least to some extent. There is a lot of uncertainty about the key triggers that are causing systems to fail and the factors that lead natural communities to be relatively more resilient. CF plots provide a way of actively addressing this uncertainty and countering collapsing vegetation systems.

In this document we argue for the urgent establishment of CF plots across Victoria, to (1) enhance habitat resilience to the uncertain and unpredictable effects of future change by incorporating genetic and/or species diversity into restoration plantings, and (2) inform future land managers about the most effective actions to build resilience to climate change in our natural systems, especially during restoration.

We outline the benefits of CF plots to conservation of natural resources under climate change, as well as current opportunities and logistical considerations to achieve this goal. These include the potential to build on existing resources and restoration activities as well as scientific and practitioner knowledge, the utilisation of CF plots as future nursery sites and the potential for CF plots to capture pre-adapted genetic variation within and across species. Clear documentation and collaboration across sectors will be needed to maximise the benefits of CF plots for biodiversity conservation.

1. Change, uncertainty and the future of our natural systems

Climate change is currently one of the greatest emerging threats to our natural systems. Ongoing climate change in combination with other stressors that are degrading landscapes is expected to create stressful environments for biota across Australia. These stressful conditions threaten natural processes and are expected to drive major losses in biodiversity in the next few decades [1,2]. In Victoria, the past century has seen conditions become hotter and drier [3], a trend that is projected to continue together with increases in the incidence of extreme weather events involving heat, drought, fire and flooding [4].

Climate change in combination with landscape fragmentation and land use change is already impacting natural systems [5]. A range of ecological processes are being affected including species distributions contracting in some areas and expanding in others, and flowering and migration times shifting in response to recent climate change [5–7]. Changes are being seen in many terrestrial systems across Australia (https://terrestrialclimatechange.org.au). In the Victorian Alps, there is a general trend for the 'woodiness' of vegetation to increase at the expense of grasses [8] which in turn increases the flammability of vegetation, making it more prone to intense fires that are expected to become more common under climate change [9]. Bird distributions are expanding southward [10] and migratory birds are arriving earlier into south-eastern Australia [11]. Changes in the timing of key life history events has also been seen in Victoria, with earlier breeding in birds [12], flowering in plants [13,14] and emergence in butterflies [15].

Extreme climate events in particular have significant impacts. Extreme heat and drought events have resulted in wide-spread tree mortality in south-western Australia and central Tasmania [16,17]. In central Victoria, bird numbers declined during an extended drought period and did not fully recover for some species in subsequent wet years [18]. In the Monaro area of New South Wales, Manna Gum mortality is possibly due to climate-induced drought [19]. Human-mediated changes in fire regimes over the past century have significantly altered vegetation within Wilsons Promontory National Park [20].

Climate changes can also have indirect effects, altering biotic interactions such as pollinator interactions or the movement of pests and diseases into new areas [5,6]. For example, changes in the migration date of bogong moths into the Australian Alps [21] creates serious mismatches between food availability and peak activity in insectivorous mammals such as the mountain pygmy possum (*Burramys parvus*) following snow melt.

Within these changing conditions, some vegetation systems appear to have a substantial capacity to adapt. Survival of temperate forests in Victoria through the Millennium Drought suggest a degree of resilience to water stress. Alpine vegetation in Victoria appears capable of adapting to increases in average temperature of 1–1.5 °C [8]. At this stage, the key climatic and environmental triggers as well as species traits that cause some systems to fail but others to persist are still unclear.

A critical issue now is what can we do to enhance resilience in our natural systems, given uncertainty of future climates and the unpredictability of subsequent impacts. In the face of current and ongoing changes across the Victorian landscape, it is no longer adequate to simply protect historic landscapes [2]. The need to promote adaptability within our natural systems is now recognised (Victoria's Climate Change Adaptation Plan 2017–2020; Protecting Victoria's Environment – Biodiversity 2036) [22]. New proposed conservation strategies, especially around seed provenancing for plant restoration, provide an opportunity to maintain vegetation communities and conserve biodiversity in an uncertain future.

Climate Future plots aim to directly address uncertainty by creating sites that both improve habitat resilience of vegetation within the wider landscape as well as provide empirical data for developing the most effective management strategies. These plots should help conservation managers deal with challenging conditions into the future.

2. What are Climate Future plots?

Climate Future (CF) plots are resources to enhance climate resilience of our natural, vegetative landscapes and actively inform future conservation management. CF plots aim to include not only threatened but also common species and systems, supporting important functional groups. CF plots address the uncertainty of species and ecosystem responses to change, given the uncertainty of future climates, and the management actions necessary to support natural processes by

- enhancing landscape-level conservation by creating climate resilient, vegetative habitat elements within the landscape
- incorporating diversity into habitat elements to enhance resilience despite the uncertainty and unpredictable effects of future conditions on both climatic and biotic interactions
- using the best available science to incorporate pre-adapted climate genetic variation within species and diversity between species; creating vegetation nursery sites, a source of climate resilient genetic stock within pollen and seed for the surrounding landscape and future restoration
- informing future adaptive management regarding species' resilience to climate change and provenance selection for restoration

This report focuses on vegetation establishment within CF plots. Though beyond the scope of this report, animals will also play a key role in CF plots, especially plant-animal interactions, and should be included in long-term CF plot monitoring and assessment.

3. Key benefits of climate future plots

3.1. Climate ready habitat

CF plots capture a range of climate adaptation through pre-adapted genetic variation within vegetation species and diversity between species. Such diversity creates habitat more likely to maintain ecosystem function in an uncertain future. As potential climate ready habitat, CF plots benefit the site and the surrounding landscape by:

- increasing habitat area, especially when other systems within the landscape are failing
- increasing genetic and species diversity within vegetation, especially climate-adapted genetic diversity
- enhancing carbon and biodiversity values, by providing more stable, sustainable habitat

3.2. Nursery site

High genetic diversity, especially pre-adapted climate diversity, enables CF plots to act as vegetation nursery sites, seed sources for active restoration or passive dispersal into the surrounding landscape [23]. As conditions change, natural selection acting on the diversity within CF plots will create a collection of individuals and provenances most fit to new conditions, and therefore best suited as seed sources for future generations.

3.3. Knowledge building for management

Despite a large body of scientific research regarding species' climate limits, adaptability and predicted distribution changes [24,25], modeling and predictions can only inform management so far. Beyond this, empirical data is required to understand how species will respond to climate changes, in combination with landscape fragmentation, altered land use and potential changes in biotic interactions. CF plots enable testing of predictions and proposed management strategies, over long time scales, to provide answers to questions like:

- where and how widely does seed need to be sourced to create climate resilient restoration?
- how much environmental and climatic variation, beyond their current known climate distribution can species tolerate?
- what is the capacity of species and ecosystems to adapt to changing conditions?

3.4. Adaptive management

CF plots create a dynamic resource for long-term adaptive conservation management by providing ongoing data on species responses and management actions over time. Long-term studies are essential to distinguish yearly or short-term variation from long-term trends [24,26] and will be critical for informing future adaptive management. CF plots actively support adaptive management strategies outlined in the Victorian Biodiversity Strategy [22] by

- providing continual, long-term data on species and system responses as conditions change, especially extreme events, and the most effective actions to support resilience
- enabling improved management in response to new data
- facilitating transitions from current to future management approaches [2], including novel strategies to address as yet unknown situations, by empirically testing different management options

3.5. Community engagement and awareness

CF plots provide an opportunity to engage with the wider public around the effects of climate change and actions that can help mitigate these. CF plots can assist groups already engaged in restoration, providing information to improve outcomes and success of plantings. More broadly, they can increase awareness of the impacts of climate change on vegetation, including potentially dramatic changes in some systems, and the active management strategies needed to support our natural vegetative systems.

4. Existing opportunities & knowledge

There is an urgent need to pre-empt the uncertainty of future environmental and climate change and establish a long-term resource now. In addition to this urgent need, we are in an opportune position to establish CF plots, being able to build on both a rapidly growing body of scientific research regarding impacts of climate change and CF-style efforts already being made.

4.1. Research

CF plots can draw on an extensive body of research regarding climate-related species variation and proposed methods for utilising this natural variation to conserve biodiversity [24,25,27]. Known climate-related genetic and trait variation can be used to select pre-adapted vegetative material for CF plots, whilst mechanistic models can guide the selection of traits and time points most informative for assessing impacts of climate change. Data from species distribution and future climate modeling can provide alternative provenances or even species for a site as well as identify priority regions or ecosystems for CF plots, those known to be particularly vulnerable to climate change.

4.2. Building on knowledge and experience from other CF style schemes

CF plots in Victoria can build on experience and knowledge from recent local and international efforts to create CF-style plots. Large scale experiments have been established to assess provenance fitness of vegetation in relation to climate in North America, e.g. Southwest Experimental Garden Array (SEGA http://www.sega.nau.edu/) and Forestry Trials in Canada, and in Australia, e.g. Australian Low Rainfall Tree Improvement Group [28] and experimental collaborations between Greening Australia and the University of Tasmania [29]. Combined with experiences from forestry and agriculture trials, and small scale efforts within current restoration sites across Victoria [23,30], there is a strong knowledge base to help facilitate the creation of CF plots.

4.3. Existing resources

A history of trial plantings across Victoria and Australia provide existing resources that can help to rapidly build a wider CF plot network. Predominately forestry, but more recently small scale restoration and larger connectivity plantings can contribute to CF plots if original source information for the planted material is available. By linking together with specific CF plots, these plantings can significantly contribute to assessing climate impacts, especially older plots that have already experienced environmental change.

5. Making Climate Future Plots a reality

What are the key elements to create an effective CF plot – a resource that captures enough pre-adapted climate variation to counter future uncertainty and create long-term sustainable vegetative habitat? The following are a series of key considerations that will help create resilient and informative CF plots.

5.1. What to include?

CF plots need to contain a diverse range of climate adapted provenances to ensure that appropriate provenances are present, covering uncertainty around future climate conditions. There is a wealth of scientific knowledge that can be drawn on to select species and provenances within species to create a diverse site (refer 4.1 Research). Existing resources such as guidelines for climate-adjusted provenancing [31,32], species distribution modeling programs (e.g. Maxent [33]) and assessment of future climate analogues (e.g. Climate Change in Australia; https://www.climatechangeinaustralia.gov.au/) can all assist in selecting an appropriate diversity of provenances and species for a given site. Where provenance success may be influenced by other non-climatic environmental factors, such as soils, site matching for these environmental attributes will also need to be considered.

5.2. Scale & Location

There is flexibility in the size, shape and scale of CF plots, depending on the nature of the vegetation community. For example CF plots aimed at capturing climate variation for an alpine heathland will require less physical space than plots capturing similar climate variation for a widespread Eucalypt woodland. Large CF plots that include a number of provenances, species and individuals have the potential to act as more effective nursery sites into the future. Decisions around size and scale need to be made in consultation with managers.

There is also flexibility in the arrangement of CF plots within the landscape, depending on the availability of land. Whilst a single large CF plot is ideal, a series of small plots across a region can also function as a CF plot network. In regions with existing restoration projects, the addition of two or three provenances in a restoration site, replicated across multiple plots within the region, can create a CF network for little additional cost or logistics.

Strategically locating CF plots across Victoria will help maximise both information for management and habitat resilience within the landscape. CF plots could initially target ecosystems or regions along environmental gradients, capturing both temporal and spatial climate differences. For instance, gradients may encompass 10 to 20 plots extending from high elevation sites (near the alpine tree line) to Central Victorian Uplands, or from the Victorian Volcanic Plains through to the Murray Mallee area. These gradients encompass several Catchment Management Authorities and a number of Ecological Vegetation Classes.

5.3. Clear design & documentation

Critical to the success of CF plots is clear site design and documentation [29]. To monitor provenances performance, especially after extreme events or stress, documentation including the original source location and where that material was planted within the CF plot are essential.

A replicated design, with multiple plantings of each provenances across a CF plot, will enable impacts of climate change to be separated from other factors such as microclimate and large mammal predation that can cause provenance failure independent of climate change. Intervention actions can also be included in the plot design to protect plots from non-climate risks [29,30]. These may include fire breaks, weed control or fencing to minimise non-climate change related loss within CF plots, such as browsing by feral deer.

Finally, for the long-term utility of CF plots, site data needs to be stored in a location and manner that is accessible to both current and future personnel, such as through the NCRIS funded Terrestrial Ecosystem Research Network portal (http://www.tern.org.au).

5.4. Funding

There is already large investment in restoration, through conservation management programs as well as carbon offset plantings. Integration of CF plots into current restoration projects will not only enhance climate resilience and biodiversity outcomes for these projects but also enable CF plots to be established for minimal additional cost. The creation of diverse CF plots will be facilitated by improved cost structures for restoration, that allow for higher initial per tree costs with the ultimate benefit of increased long-term restoration success.

Larger scale, more complex, research-focused CF plots will require additional capital funding, ideally via collaboration with organisations currently involved in large-scale restoration. Given the substantial current (and anticipated future) investments into restoration, and climate change management and mitigation, determining which strategies provide the best long-term biodiversity outcomes will be essential to maximise investment returns. Initial capital investments in large-scale CF plots would therefore result in long-term benefits including cost savings and greater biodiversity outcomes.

5.5. Monitoring & revisiting

Monitoring performance in CF plots over time is key to informing adaptive management. There is a large body of research that can be drawn on to help determine those traits and time points that provide the best indicators of fitness including impacts of climate change [24]. In addition, monitoring of the CF plot site prior to establishment or monitoring of an appropriate good-quality, natural reference site provides a baseline for comparing performance of provenances and management strategies within the CF plot.

CF plots are designed to be a dynamic, learning and evolving resource, not a static one-time experiment. As such, adaptive management can occur within the CF plot, for example, replacing provenances lost following an extreme event with a better performing provenance. In this way, CF plots retain their primary function of providing climate resilient habitat, whilst also continuing as a learning resource for management.

5.6. Consolidate past efforts and data

Consolidating past planting efforts will maximise information available for monitoring climate change effects. As mentioned above (4.3 Existing resources), collating available information on existing forestry trials and restoration plantings will help build a larger CF plot network.

5.7. Collaboration across sectors and wider community

Collaboration across all sectors including restoration practitioners, public and private land managers, policy and science will create CF plots of maximum benefit to biodiversity management. Combining extensive experience of practitioners with research knowledge of scientists will enhance CF plot success. Subsequent communication of site changes over time to land managers and ultimately policy developers will ensure continual improvement of natural resource management under climate change. In addition, engaging with the wider community, including promoting the benefit of CF plots, will assist in establishing individual CF plots within current community restoration plantings as well as contribute to broader-scale CF plot networks.

5.8. Learn by doing

While there is a wealth of scientific research and practical knowledge that can be used to make sensible, considered decisions regarding initial CF plots, a lot of new information will emerge to guide future efforts. CF plots are therefore an active learning tool not only for restoration and management but also for planning additional CF plots. This can help to ensure actions that increase climate resilience, no matter what future climates arise. Uncertainties should not hinder the creation of these plots [27]. Rather CF plots actively address uncertainties, around climate effects, management actions and how we can enhance resilience in our natural, vegetative systems.

6. Example of a Climate Future Plot

Imagine a small, 0.1 ha site for restoration in Central Victoria, restoring previous Grey Box Grassy Woodland. To enhance pre-adapted genetic diversity in our primary restoration species, Grey Box (*Eucalyptus microcarpa*), we employ climate-adjusted provenancing to augment a local provenance. Given the modest size of the site, we opt for two additional provenances along a climate gradient; for instance given predicted increases in temperature for Victoria, we select a provenance from a location 1 °C (Wagga Wagga, NSW) and 2 °C (Dubbo, NSW) warmer than current central Victoria. To create redundancy in ecological function, should this site become unsuitable for

Grey Box in the future, we draw on knowledge of associated trees species and / or species distribution modeling and include samples of Yellow Box (*E. melliodora*) and White Box (*E. albens*). We may also choose to translocate a closely related species occurring in predominately hotter climates and therefore potentially able to fill a similar ecological niche whilst being pre-adapted to hotter conditions, e.g. *E. woollsiana*, a close relative of Grey Box found primarily in northern NSW and southern QLD. To increase species and structural diversity, shrubs such as gold-dust wattle (*Acacia acinacea*) and drooping cassinia (*Cassinia arcuata*) are included amongst the tree plantings, following climate-adjusted provenancing principals to ensure climate resilience of the shrub layer. Finally, to ensure redundancy and mitigate against random effects across the site, this design is replicated with multiple plantings of provenances and species. Ongoing monitoring at this site, and potential reference sites in nearby natural remnant habitat, can inform management on the performance of difference provenances and species in terms of survival and seed output. Effects on faunal biodiversity could also be assessed, such as by regular sampling of invertebrates. Figure 1 shows an example of what a component of this Grey Box Grassy Woodland CF plot might look like.

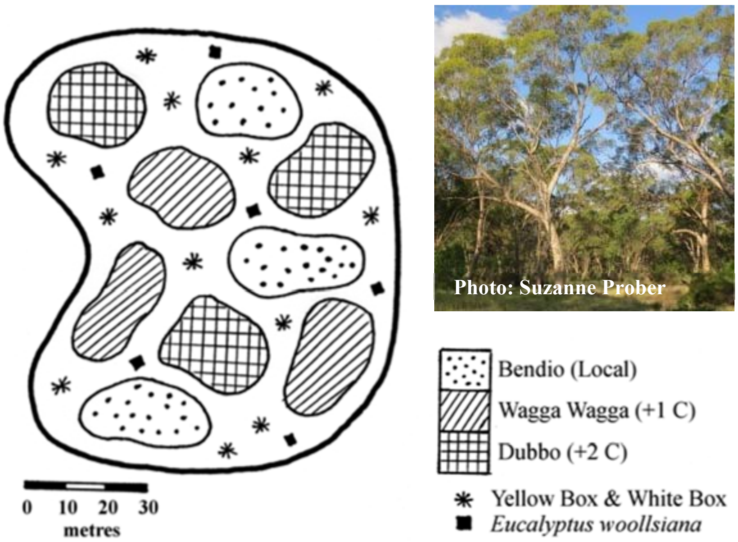

Figure 1 Example of a component of a Climate Future plot for a Grey Box Grassy Woodland restoration in Central Victoria. The restoration effort includes replicated patches of *E. microcarpa* from three provenances (Bendigo, Wagga Wagga and Dubbo) as well as including species from other regions that are likely to persist well under future climate conditions.

7. Moving forward

The time for discussion and debate around climate change is well and truly behind us. Climate change is already impacting our natural systems and the mixed success of current restoration projects coupled with uncertainty about projects into the future suggest a new approach is required. Despite uncertainty, we need to take action now to build climate resilience into our restoration plantings as insurance for habitat into the future.

There is a wealth of scientific research that can be drawn on to make sensible, considered management decisions. However we won't know which approach is best until empirical data are assessed. Long-term data is required to understand species and ecosystem responses to climate and to distinguish long-term trends and changes from short-term variation.

Uncertainty, around future conditions and management actions, does not need to hinder active management towards climate resilient habitat. Rather CF plots aim to actively address this uncertainty, providing the information that discussions and predictions alone cannot answer. In these ways, CF plots are a dynamic resource to build climate resilience into our natural, vegetative systems and provide continual feedback for future land managers in an uncertain future.

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